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FUZZY VARIABLE SPEED LIMIT DEVICE MODIFICATION AND TESTING – PHASE II

In 1998, Northern Arizona University (NAU) and the Arizona Department of Transportation (ADOT) designed and implemented the prototype of a variable speed limit (VSL) system for rural highways that utilizes information provided by a typical Road Weather Information Station (RWIS). This joint project produced a fuzzy logic control system that continuously displays highway speeds appropriate to the atmospheric and road surface conditions at locations of interest along the I-40 corridor in rural northern Arizona. Fuzzy logic is a system of mathematics that allows the vagueness of linguistic concepts to be represented by sets with imprecise boundaries. In fuzzy logic, the membership of an element in a set is not all or nothing but can assume values between these two extremes. Working with degrees of membership allows the imprecision inherent in natural language to be represented and it supports a form of approximate reasoning that attempts to model the way human beings reason. Therefore, the fuzzy logic controller for the VSL system developed by NAU and ADOT uses a reasoning process similar to that of a human expert to determine a speed limit at a given location that is appropriate to the prevailing atmospheric and road surface conditions at that location.

Background

During the development of the fuzzy logic algorithm for the VSL system created by NAU and ADOT, none of the RWIS sites along I-40 in Arizona were providing the complete data set needed for full utilization of that algorithm. The primary objective of the project described in this document was to fully upgrade an RWIS site on I-40 so that it could be used as a test site to monitor the complete data set of atmospheric and road surface conditions that can be utilized by the fuzzy control algorithm. A second objective was to enhance this upgraded site so that it would also supply traffic flow data. The remaining objectives of the project were to collect atmospheric, road surface, and traffic data over a wide variety of weather conditions and to use this data to assess the reliability and appropriateness of the speed limits produced by the VSL system.

Enhancement of RWIS Test Site

The RWIS site called Riordan, five miles west of Flagstaff, was selected as the project test site. This site was modified so that it could supply traffic data as well as all of the atmospheric and road surface data required by the full VSL prototype system developed by NAU and ADOT in a previous project. This included upgrading existing sensors at the site, installing new types of sensors, installing new computer software and hardware, installing power and telephone lines, and calibration of sensors. Acquisition, installation, and integration of all this equipment encountered numerous delays and was not completed until the final weeks of the project. This meant that RWIS and traffic data collection did not begin until the allotted project time was nearly complete.

Reconsidering Software Needs

When the project first began one of the project partners, Surface Systems Inc. (SSI), advised its NAU and ADOT partners that significant improvements had been made in the computer software available for the RWIS test site. It was suggested that the list of computer software and hardware to be acquired as detailed in the original project proposal should be modified to include the latest software (and its associated hardware) available through SSI. This software, the ScanWeb package, provided a web-based monitoring system that could be expanded to integrate RWIS data collected by multiple vendors. The computer software and hardware to be acquired for the project was renegotiated because it was determined by ADOT that this new software package did represent a significant improvement over the software originally proposed. The money awarded for the project was already determined and fixed but the new software required additional funds. To accommodate for this, SSI increased its cost share to the project and provided the new software and licenses needed to bring ScanWeb into the project. Although this process of renegotiation took several weeks to work out, the resulting software was clearly superior to what was originally planned for the project.

Power And Telephone Line Installations

ADOT and SSI upgraded the battery capabilities of the Riordan test site for backup operations and in order to provide seven-day autonomy for data at the site. In the event of a power loss, battery backup will allow the site to continue in full operation for more than a day. If power is not restored beyond this time, all data at the RWIS site will be stored safely for seven days from the time RWIS operations failed due to the loss of battery backup.

ADOT brought a power line and a telephone line into the Riordan site. This was a difficult and time-consuming process, which involved a number of activities. Incurring a number of unavoidable delays, these activities took several months to complete. Nonetheless, all partners in the project (ADOT, SSI, and NAU) felt that the advantages offered by bringing power and telephone lines into the RWIS test site justified the potential delays in the project schedule. The existence of power and telephone lines at the test site assures greater reliability of the data communications system during severe weather conditions and it brings a significant increase in bandwidth to the communications system.

Sensors and Communications Upgrades

Numerous sensor upgrades and additions were performed at the RWIS test site. In addition to this, improvements in communications capabilities were made at the RWIS site and at the district office. This included software and hardware upgrades to improve communications capabilities at the RWIS site. It also included software upgrades for atmospheric and road surface sensors plus a traffic monitoring system and a new visibility sensor.

Development Of Data Analysis Tools

The delays discussed above resulted in too little data being collected during the winter months when the most extreme weather conditions exist. Consequently, the time allotted for data collection will need to be extended. Nonetheless, there was much that could be done in preparation for the required data analysis. An interactive addition to the variable speed limit project web site was constructed that will allow project participants to perform different types of analysis on the data when it is collected.

Currently there are two graphical user interfaces (GUIs) that have been developed to allow users to specify the analysis they want performed on the RWIS and traffic detection data. The first interface allows users to select a set of atmospheric and road surface conditions of interest and it allows for specification of the period of time over which the analysis is to be conducted. Once these conditions are submitted, the project database is searched for all instances when the specified conditions were in effect. A distribution of speeds will be displayed to the user that will compare the speed computed by the fuzzy control algorithm for the specified conditions with the actual distribution of traffic speeds when the specified conditions were in effect.

The second interface allows users to select a speed limit that would be computed by the fuzzy algorithm and it allows for specification of the period of time over which the analysis is to be conducted. For example, if the speed 45 mph were selected, this would indicate an interest in all configurations of atmospheric and road surface conditions that resulted in the fuzzy algorithm computing a speed of 45 mph. Once a speed and time period are submitted, the project database is searched for all configurations of conditions that resulted in the fuzzy control algorithm computing the specified speed. A distribution of actual traffic flow data for the specific speed selected will be displayed to the user. The speed distribution provided will compare a speed computed by the fuzzy algorithm with the actual distribution of traffic speeds for all conditions over which the specified speed was in effect.

Conclusions and Recommendations

The three essential aspects of any speed management system are engineering, enforcement, and education. We recommend that the work described in this report be considered in this context. Furthermore, we recommend that the work just completed, the Fuzzy Variable Speed Limit Device Modification and Testing Project, be thought of as Phase II, of a larger four-phase project.

Phase III: Immediate Future Research

The engineering issues of a recommended Phase III of the project would include data collection over diverse weather conditions and analysis of the fuzzy control system developed in Phase I. Comparison of actual traffic flow data with the operation of the fuzzy algorithm would complete this analysis. The RWIS site at Riordan is now fully functional and is sending the complete data set needed for analysis of the fuzzy algorithm to the ADOT district office in Flagstaff. The data is being archived and managed at the district office.

Another issue related to engineering would be to get potential vendors to consider new system designs for modular, low-cost variable speed limit systems and perhaps to work with one or more of these vendors in the development of these low-cost prototype VSL systems.

The educational issues to be engaged in Phase III would involve a formal analysis of the legal and liability issues related to the new speed management system. Essential to the future success of any variable speed limit system is for everyone concerned (courts, police, motoring public, etc.) to have a common understanding of the assumptions, expectations, and liabilities associated with that system. There are variable speed limit systems currently deployed in a number of locations both here, in the United States, and in other countries. The lessons learned and the procedures established in these other locations should be considered carefully. No public display of the variable speed limits would occur in Phase III because such a display must come only after the legal and liability analysis is complete.

Finally it would also be important in Phase III to begin a formal analysis of law enforcement techniques needed to support the new system. A number of enforcement issues must be addressed in order to know how best to make the design of a variable speed limit system compatible with a supportive law enforcement policy. Here again, studying the lessons learned and the successful procedures established in other states and countries, would be an important aspect of this effort to devise an effective and just set of law enforcement policies.

Phase IV: Longer Term Future Research

In a recommended Phase IV of the project, the engineering aspects would involve implementation at limited sites of the new variable speed limit systems for general use. For some period of time, continuous monitoring of the systems would be needed in order to improve and refine them. Educational efforts would use the results of the legal and liability studies in Phase III to bring a common understanding of the relevant issues to the courts, the police, the Department of Transportation, the motoring public, and everyone else whom might be affected by the new variable speed limit systems. Enforcement efforts in this fourth stage of the project would involve the continuous monitoring of the appropriateness and effectiveness of the law enforcement policies that had been established in Phase III of the project.

The full report: ***Fuzzy Variable Speed Limit Device Modification and Testing – Phase II*** by John Placer (Arizona Department of Transportation, report number AZ-466(2), published July 2001) is available from the Arizona Transportation Research Center, 206 S. 17th Ave. MD075R, Phoenix, AZ 85007, telephone 602-712-3138; fax 602-712-3400.